How output diversification affects bank efficiency and risk:  
an intra-EU comparative study

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**Abstract**  
This paper examines how banks have been diversifying away from traditional financial intermediation activity into noninterest income business and how this shift has affected their efficiency and risk-taking behaviour. To this end, we construct a global best-practice efficiency frontier following the Stochastic Frontier Approach and relying on the technique of Battese and Coelli (1995), which permits the estimation of the frontier and of the coefficients of efficiency variables in a single-stage. We opt for an application of this model to the EU-27 performing cross-member comparisons that provide us with substantial information concerning the impact of output diversification on the European banking systems. Our empirical findings suggest that diversification has a positive impact on bank efficiency.

*Keywords*: nontraditional activities, efficiency; risk; financial intermediation; EU banks
1. Introduction.

Over the past couple of decades or more, the extensive regulatory changes and the technological advances have transformed financial systems to a great extent. Banks have reacted to the challenges posed by the new operating environment by developing new products and services and updating the already existing ones, which allowed them to diversify the product mix of their portfolio. The traditional business of taking deposits from households and making loans to agents that require capital has thus declined in favour of a considerable growth in activities that generate non-interest income and are not necessarily reported on banks’ balance sheets.\(^1\) In consequence, the sources of revenues and profits of banking institutions have been diversified as noninterest income relative to its interest counterpart from traditional financial activities has dramatically increased.\(^2\)

The present work assesses the effect of alterations in product mix on the performance and risk-taking behaviour of banks within the new financial environment. Differently phrased, this paper examines how banks have been diversifying away from traditional financial intermediation activity into noninterest income business and how this shift has affected their overall performance, which is measured in terms of cost and profit X-efficiencies.

We use data from the EU-27 to test whether the shift towards the new financial intermediation business has affected the Union’s banking systems uniformly. That is, we estimate whether European banks have jointly improved their performance by increasing their efficiency and lowering their risk after diversifying their portfolios. An intra-EU comparison between the 15 long-term members and the group of the 12 states that recently ascended to the Union is further made bearing in mind that -almost until the commence of the current decade- the financial markets of this latter set of countries has been considered as being under development based on the EBRD (2007) classifications.\(^3\) Such comparative analyses can provide us with

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\(^1\) A number of studies has documented this trend using data from different banking industries. See, e.g. Rogers (1998), Rogers and Sinkey (1999), and Stiroh (2004) for US banking, Rime and Stiroh (2003) and Tortosa-Ausina (2003) for the Swiss and Spanish banking sectors, respectively.

\(^2\) It has to be mentioned here that banks have long earned noninterest income by charging their customers fees in exchange for a number of traditional services like checking and cash management, safe-keeping services (e.g. insured deposit accounts and safety deposit boxes), investment services (e.g. trust accounts and long-run certificates of deposits), and insurance services (e.g. annuity contracts). This sort of income, however, has been a very small fraction of banks’ total income until recently.

\(^3\) An exception is Cyprus, whose financial system has been considered as developed well before its entrance in the Union.
substantial information concerning the performance of banks within the Union, thus giving us a thorough picture of the level of integration in the European banking environment as a whole.

In order to render cross-country comparisons meaningful, it is of importance not only to allow for variation in relative factor prices across countries, but also to account for differences in the overall environments within which banks operate. Several bank efficiency studies follow a two-stage approach, where efficiency measures derived—either parametrically, or non-parametrically— in the first stage are then regressed on a number of determinants reflecting differences in macroeconomic conditions, competitive structure, ownership status, regulatory regimes and so forth. Such two-step estimation procedures, however, are rather problematic. The reason is that the efficiency scores obtained in the first stage are either based on country-specific frontiers, or in the case that a global frontier⁴ is used environmental differences are not taken into account as this constitutes a task of the second stage. Moreover, the parametric two-stage approaches produce inconsistent coefficients for the reason that the assumptions made in the first step concerning the distribution of the inefficiency component of the error term are violated in the second stage (see Wang and Schmidt, 2002).⁵ On the other hand, efficiency estimates obtained non-parametrically in the first step have proved to be serially correlated, and consequently standard approaches to inference (such as censored regressions) are invalid.⁶ In either case, meaningful conclusions concerning the comparison of efficiency estimates across countries may not easily be drawn with two-stage empirical methods.

This might explains why efficiency comparison studies have turned to follow single-stage estimation approaches.⁷ These studies are in two distinct types: those that construct separate efficiency frontiers for each sample country and then perform pairwise comparisons (Berger and Humphrey, 1997; Casu and Girardone, 2005) and those which pool the data and define a common frontier for all the countries under scrutiny controlling for country-specific characteristics (see e.g. Pastor et al., 1997). Yet,

⁴ A global frontier is made up by the best-practice institutions of the whole sample.
⁵ Whereas in the first stage it is assumed that the inefficiency component of the error term has a truncated-normal distribution, whose point of truncation depends on bank-specific variables, the assumption is vitiated in the second stage, where a normal distribution is assumed instead.
⁶ In fact, Simar and Wilson (2007) propose a bootstrap procedure to be used in the second-stage regressions, which allows for valid inference. In another paper, Balaguer-Coll et al. (2007) also acknowledge this drawback and suggest bivariate kernel regressions in the second stage.
⁷ Berger (2007) offers an extended survey of all the studies that employ single-stage empirical methods to make cross-country comparisons of banking efficiency.
studies of the first type do not account for environmental differences. This is to say, when proceed in making cross-country comparisons, we can only infer how dispersed banks in different countries are away from their national frontiers, and not whether a banking system operates more or less efficiently relative to some other.

In the current study, we perform comparisons across EU member states constructing a global best-practice efficiency frontier following the Stochastic Frontier Approach (SFA) and relying on the technique of Battese and Coelli (1995), which permits the estimation of the efficiency scores and its correlates in a single-step. Cost and profit global frontiers are estimated with and without the inclusion of non-traditional activities in order the impact of diversified product offerings on bank performance and risk to be explicitly measured. Output diversification is captured by two alternative measures: Off-Balance-Sheet (OBS) items and the level of noninterest income relative to traditional (interest) income. Risk plays a central role in our analysis as non-traditional instruments comprise a basic tool for financial institutions to distribute risk across different participants. To study variation in the risk-taking behaviour of banks, we consider three categories of risk, namely credit, liquidity and capital risk. A set of country-specific and control variables are further utilized to capture differences amongst the EU banking systems.

To our knowledge, this is the first study that provides a cross-country comparison of the impact of non-traditional activities on bank performance. Relevant studies have been exclusively focused on single banking industries (mostly that of US) with only exception that of Vennet (2002). Yet, Vennet, although using data from 17 European banking markets, does not proceed in making any cross-country comparisons as he is only interested in estimating the performance among different forms of financial institutions. Moreover, the methodology of Battese and Coelli (1995) employed in this paper has been applied only in Fries and Taci (2005) and Lensink et al. (2008) so far. Our work, however, is differentiated from both these papers as the former aims to estimate the deregulation process in the Central and Eastern Europe and the latter to examine the link between efficiency and ownership thus accounting for non-traditional activities only parenthetically. Last but not least, the present paper offers the ground to empirically test the dilemma of focus versus diversification, which we think that has not been addressed thoroughly in the context of financial intermediation theory.
The rest of this paper proceeds as follows. Section 2 briefly reviews the relevant literature, whereas section 3 illustrates the theoretical underpinnings of the paper. Section 4 presents the cost and profit efficiency models and the estimation methodology used; a description of the data set and of the variables employed in the analysis is also offered. Section 5 displays and discusses the empirical findings, and section 6 provides some concluding remarks paving the way to further research.

As noted above, the new financial intermediation environment that has been established through the deregulation process and the technological progress has forced banks to turn into noninterest income business. However, a number of bank performance studies—even some of the latest ones—do not consider the relevance of this sort of business (Berg et al., 1992; Grifell-Tatjé and Lovell, 1996; Wheelock and Wilson, 1999; Maudos et al., 2002; Bonin et al., 2005; Lensink et al., 2008).

In fact, literature has only recently turned to account for non-traditional activities by employing them as an additional output in the empirical models used. Several various measures have been utilized to capture this new type of banking activities. Altunbas et al. (2000) examine the link between efficiency and risk in the Japanese commercial banking sector over the period 1993-1996 employing the parametric SFA. Moreover, Altunbas et al. (2001a) evaluate cost and profit efficiencies as well as the impact of technical progress in the German banking market between 1989 and 1996 also employing the SFA together with the Distribution Free Approach (DFA). The analysis is extended to the EU-15 in Altunbas et al. (2001b). All the aforementioned works proxy non-traditional activities by the nominal value of OBS products. The same measure is used in Casu et al. (2004), who compare parametric and non-parametric estimation methods of bank productivity of the largest European economies.

In studying the performance of Turkish banks, Isik and Hassan (2003) incorporate the risk-adjusted value of OBS activities according to the Basel Accord in their empirical models. They assert that such an adjustment provides conformity with other bank outputs in terms of credit risk. Other studies use other earning assets to capture the entanglement of bank into nontraditional activities (Dietsch and Lozano-Vivas, 2000; Maudos et al., 2002). To continue, Drake and Hall (2003) use the non-
parametric Data Envelopment Analysis (DEA) to estimate the efficiency in the Japanese banking sector using data on net fee and commission income and other net non-interest operating income to capture nontraditional activities. Several later studies also used noninterest income in their analyses (e.g. Allen and Liu, 2007). Tortosa-Ausina et al. (2008), who estimate the efficiency and the productivity change of Spanish savings banks utilizing the DEA and the Malmquist index respectively, enriched noninterest income with income from securities, thinking that several savings banks participate in the privatization process of a number of public companies.

Notwithstanding the incorporation of alternative measures of nontraditional activities in the vector of outputs, none of the above studies estimates the clear effect that new financial products have on the performance of banking sectors. This gap is bridged by a recently developed strand of literature, which explicitly focuses on bank performance-nontraditional activities nexus. Studies that belong to this strand compare performance measures derived by alternative models specifications, that is, with and without the inclusion of non-traditional items. The origins of this strand can be traced back to 1994, when DeYoung explicitly addressed the effect of noninterest and fee income on the efficiency of US commercial banking sector. He estimated a cost efficiency frontier and found that the standard formulation, which disregards nontraditional income devalues efficiency for banks with a large share of this type of income –the so-called universal banks.

Several later works followed that of DeYoung (1994) in evaluating the impact of nontraditional activities on the performance of banks. However, academic research has been almost exclusively focused on the US banking system. Jagtiani et al. (1995) measure scale and scope economies to investigate whether OBS items have an effect on the efficiency of US commercial banks. OBS items are captured by guarantees (standby letters of credit, commercial letters of credit, and loan commitments), and foreign currency and interest rate transactions (swaps, options, futures, and forward contracts). Rogers (1998), moreover, gauges the significance of taking nontraditional services into account using US commercial banking data. To this end, he formulates cost, revenue, and profit frontiers to estimate efficiency with and without

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nontraditional products proxied by net noninterest income employing the DFA. The same proxy measure is used by Rogers and Sinkey (1999), who empirically assess the level of involvement of US banks in nontraditional activities, and Stiroh (2000), who apply DFA in the US bank holding companies to examine cost and profit efficiencies as well as productivity growth and scale economies over the years 1991-1997. The latter study also uses a Basel-based measure (CEM) that converts all OBS activities to credit risk equivalents. Net noninterest income, CEM, and AEM (an asset equivalent measure that uses the rate of return on balance-sheet items to capitalize the noninterest income from OBS activities) are utilized in the empirical work of Clark and Siems (2002) that estimates the importance of nontraditional activities in the performance of US commercial banks employing both the SFA and the DFA.

As already mentioned, there is just a handful of papers that use data other from US to estimate how nontraditional items affect bank performance. To start with, Vennet (2002) employs SFA to investigate whether or not there are efficiency differences between specialized and non-specialized financial institutions in Europe, where non-specialized institutions consists of universal banks and conglomerates that offer both traditional and non-traditional services. The latter form of services is captured by noninterest income. Furthermore, Tortosa-Ausina (2003) employed a cost-oriented DEA in order to examine the role of noninterest income on the efficiency of the Spanish commercial and savings banks for the 1986-1997 period. Rime and Stiroh (2003) measure cost and profit efficiency as well as economies of scale and scope of large Swiss banks. Output is defined in such a way as to include two proxies for nontraditional services: the CEM of OBS derivative activities and the trading and portfolio management activities. In a recent study, Casu and Girardone (2005) employ the Malmquist index to test whether the increase in the nominal value of OBS activities have an effect on the productivity of five European banking sectors over 1994-2000.

Although nontraditional activities’ measures and estimation techniques vary in the studies reviewed here, the empirical findings converge to the conclusion that ignoring nontraditional activities leads to a misspecification of bank output. More

9 Service charges on deposits are subtracted from noninterest income to make it a more accurate proxy for nontraditional activities.
10 Exceptions are the study of Jagtiani et al. (1995), which finds no impact of nontraditional activities on bank performance, and that of Clark and Siems (2002), which concludes that the effect of nontraditional activities depends on the estimation frontier examined.
specifically, average efficiency levels are enhanced when these types of activities are taken into account. This happens mainly because the resources used to produce these outputs are considered in the input vector, whereas they are not considered as outputs. This result corroborates the growing importance that nontraditional products have in the operation of banks.

3. Theoretical Background.

3.1. The financial intermediation theory: the transition from the traditional to modern approach

The traditional financial intermediation theory relies basically upon the vitiation of the Arrow-Debreu complete markets paradigm and of the Modigliani-Miller theorem. According to the former, firms and governments are financed by households via financial markets. As these markets are assumed to be perfect and complete (i.e. there are no transaction costs and no credit rationing, whilst there is a full set of contingent markets), the allocation of resources is Pareto optimal and hence there is no role for intermediaries. The Modigliani-Miller theorem, on the other hand, assumes that all households are involved and there is full participation in markets. This implies that financial structure is irrelevant as households can construct portfolios offsetting actions of intermediaries and thus intermediation cannot add value.

In real life, however, imperfect information and transaction costs that exist in the economy restrict the scope for direct financing and vitiate the Arrow-Debreu model of resource allocation. In addition, there is evidence that full participation does not hold in practice and thus the Modigliani-Miller theorem is not valid. Accordingly, financial institutions intervene between savers and borrowers taking advantage of market frictions.

Financial intermediaries allow transaction costs to be shared thus having an advantage over individuals.\textsuperscript{11} Concerning the existence of asymmetries in

\textsuperscript{11} The two major aspects of financial intermediary activity are brokerage and qualitative asset transformation. Brokerage is usually referred to as “soft” intermediation, while asset transformation as “hard” intermediation activity. By brokerage, banks match transactors with complementary needs asking for a fee-based compensation. Banks take no particular position, although reputation risk is inherent in brokerage activity. Moreover, they have a basis of cost of gathering information; yet, information can be reused -either cross-sectionally or through time- at zero cost. Examples of banks’ brokerage activity are transaction services, financial advice, screening, origination, issuance, and funding. As regards qualitative asset transformation, it refers to the transformation of the attributes of an asset (e.g. monitoring, management expertise, guaranteeing, liquidity creation etc.).
information, intermediaries can signal their informed status by investing their capital in assets about which they have special knowledge. Moreover, an intermediary can overcome the problems that asymmetric information generates by acting as “delegated monitor” (Diamond, 1984).

In recent decades, however, transaction costs have been reduced and information asymmetries have shrunk as information has become cheaper and more easily available. However, these changes have not coincided with a decline in intermediation. In contrast, the volume of intermediation has enhanced. Indeed, whereas banks’ total assets as a percentage of financial intermediation assets have fallen in all developed financial sectors and the total number of banking institutions has dropped, the intermediation role of banks has been augmented. Apparently, the traditional intermediation theory, which stresses transaction costs and asymmetric information, does not satisfactorily explain the observed increase in intermediation activity. This happens because financial intermediaries have lately involved in several emerging financial markets, where they deal with a complex maze of new financial instruments. Financial institutions use these markets to manage risk and to trade all this volume of novel products.¹²

In Europe, which is on the focus of the current study, limits on banking activities were removed with the implementation of the Second Banking Directive of 1989 and the Directive on Investment Services. These two enactments allowed all banks to operate outside their home country and engage in all sorts of financial services. As a result, a number of bank consolidations within and across EU member states have taken place over the past years that led to the emergence of universal financial institutions, which provide a broad diversified range of activities that generate substantial amounts of noninterest income.

3.2. Product diversification and the risk-taking behavior of banks
The relationship between product diversification and bank risk can be viewed from two different perspectives: the one describes a negative correlation, whereas the other a positive. Both aspects are portrayed in detail below.

¹² Modern financial products have rather stable distributions of returns as they do not depend much on changes in economic conditions. This implies that investors have to monitor their asset portfolio less frequently thus reducing their participation costs.
Following the literature (DeYoung and Roland, 2001; Stiroh, 2004), there are two channels through which –at least, in principle- product diversification leads to a reduction in risk. The first has to do with the conventional wisdom among many bank practitioners that noninterest income is less sensitive to changes in economic and business environment compared to interest income (i.e. modern financial products have a rather stable distribution of returns). Therefore, as banks rely more and more on the former type of income, they expose themselves to less risk as they manage to reduce the cyclical variation in profits and revenue. Turning to the second channel, if there is a negative or a weak correlation between the two sorts of income, then - according to the traditional banking and portfolio theories (see Diamond, 1984)- the observed increase in the share of noninterest-generating activities in the portfolio of banking items reduces the volatility of total earnings via diversification effects.

Nevertheless, there is the other side of the coin. DeYoung and Roland (2001) argue that noninterest income is less stable if compared to its interest counterpart and hence non-traditional activities may increase bank riskiness. This is mainly due to three reasons: the nature of bank-customer relationships, the input mixes, and the insufficient capital requirements for the noninterest-generating activities.

According to the first cause, traditional activities like lending generate relatively stable relationships between banks and their customers as switching and information costs for both lenders and borrowers are high and thus it is not in the interest of either side to walk away. In contrast, these costs are lower in the case of non-traditional activities. Also, the demand for these lines of business has proved not to be so stable. In accordance, whereas interest income is rather stable, noninterest income is likely to fluctuate over time.

Second, a bank can extend a lending relationship only with a burden on its variable cost (i.e. interest expense). On the other hand, if it decides to increase the volume of non-traditional services, it might have to hire additional fixed labour inputs, which leads to an increase in its operating leverage. A higher operating leverage, however, amplifies revenue volatility into higher profit volatility. Again, the involvement in non-traditional activities is related to a higher degree of riskiness.

Last but not least, banking regulations force banks to hold just a small amount of capital against fee-based activities in comparison with the amount that are forced to hold for traditional items. The differences in capital requirements suggest an enhanced
financial leverage, which is related with higher earnings volatility for non-traditional activities.

4.1 The model
We use the Battese and Coelli (1995) model that estimates bank efficiency in a single stage also allowing to control for environmental factors at the same stage. Efficiency is defined on the basis of how close a bank lies to the efficient frontier, which is determined by the best-practice bank. Using panel data the model specifies a stochastic cost frontier of the following general form:\(^{13}\):

\[
\ln C_{ijt} = C(y_{ijt}, w_{ijt}, q_{jt}; \beta) + u_{ijt} + v_{ijt},
\]

where: \(C_{ijt}\) is the total cost (measured by total expenses) that bank \(i\) faces in country \(j\) at time \(t\);
\(y_{ijt}\) and \(w_{ijt}\) are the vectors of output quantities and input prices;
\(q_{jt}\) is the vector of country-level variables (hence, there is no index \(i\));
\(\beta\) is a vector of all scalar parameters to be estimated;
\(v_{ijt}\) stands for the random error term that is assumed to be i.i.d. and have \(N(0, \sigma_v^2)\);
\(u_{ijt}>0^{14}\) captures cost inefficiency and is independently but not identically distributed, such that \(u_{ijt}\) is obtained by truncation at zero of the \(N(m_{ijt}, \sigma_u^2)\) distribution where the mean is defined by:

\[
m_{ijt} = z_{ijt} \delta,
\]

where: \(z_{ijt}\) represents the vector of observable variables that affect the inefficiency of bank \(i\) of country \(j\) at \(t\) and \(\delta\) is the vector of coefficients to be estimated.

\(^{13}\) In the case of the profit function that we use to estimate profit efficiency, we only have to use \textit{profit before taxes} instead of \textit{total expenses} as the left-hand side variable and turn the sign of the inefficiency term into negative.

\(^{14}\) The bank inefficiency component of the error term is assumed to be strictly positive, as higher inefficiency is associated with higher cost.
Using the standard translog specification of Christansen et al. (1973), Eq. (1) can be written as follows:

\[ \ln C_{ijt} = a_0 + \sum_k^a a_k \ln P_{k,ijt} + \sum_s^t \beta_s \ln Q_{s,ijt} \]

\[ + \frac{1}{2} \sum_k^a \sum_n^i a_{k,n} \ln P_{k,ijt} \ln P_{n,ijt} + \frac{1}{2} \sum_s^t \sum_t^i \beta_{s,t} \ln Q_{s,ijt} \ln Q_{t,ijt} \]

\[ + \sum_k^n \sum_s^i \phi_{k,s} \ln P_k \ln Q_{s,ijt} \]

(3)

where: \( P_k \) and \( P_n \) are the input prices and \( Q_s \) and \( Q_t \) are the output quantities.

In Eq. (3), we impose symmetry and linear homogeneity to ensure that \( C \) (Profit, in the case that profit function is used) behaves well:

\[ \alpha_{k,n} = \alpha_{n,k} \quad \text{and} \quad \beta_{s,t} = \beta_{t,s} \]  

(symmetry constraints)

\[ \sum_k^a a_k = 1 \]  

(homogeneity in prices)

Accordingly, the basic model that is estimated in a single-step by using maximum likelihood consists of Eqs. (2) and (3).

4.2. Specifications of the model

As already mentioned, we use two different frontier specifications: the first relies on the cost function and the second on the profit function. Instead of the standard profit function that takes output prices as given and let input and output quantities to vary, an alternative approach where the converse holds true is utilized to estimate the profit frontier. This latter approach is preferred in the literature (see e.g. Rogers, 1998; Stiroh, 2000; Clark and Siems, 2002) due to the lack of output price data.
Across the two frontier specifications, two separate models—an unrestricted and a restricted—are estimated to test for the significance of output diversification on the performance of banks. The output vector of the unrestricted model includes both traditional and nontraditional banking products, whereas that of the restricted excludes the latter items. In fact, we employ two unrestricted models rather than one: unrestricted model A proxies nontraditional products by including noninterest income, whereas model B uses the OBS activities to capture output diversification.

4.3 Input prices and output quantities
We follow the so-called ‘intermediation approach’ to define and measure bank output. Under this approach, financial institutions are thought of as intermediaries that transfer funds from savers to borrowers. This is to say, deposits and purchased funds are transformed into loans and other assets. Hence, financial assets are treated as outputs and financial liabilities and physical factors as inputs. We specify four outputs: total loans ($y_1$) and total other earning assets ($y_2$) to capture banks’ traditional activities, and non-interest income ($y_3$) -measured as the sum of fee income, service charges, trading revenue, and other operating income- and the nominal value of OBS items ($y_4$) to proxy non-traditional activities. As regards inputs, we employ two of them in our analysis, namely the cost of loanable funds ($w_1$), and labour cost ($w_2$). To impose linear homogeneity restrictions, we normalize the dependent variable and the input prices by cost of labour.

4.3. Risk, country-specific and control variables
Following the empirical literature, we use three different metrics to capture the variation in the risk-taking strategies of banks. These are: the ratio of non-performing to total loans to measure credit risk (Fries and Taci, 2005), the ratio of liquid to total assets to proxy liquidity risk and the ratio of total equity to total assets to proxy capital risk.

Furthermore, a couple of country-level variables are included in the empirical model to account for differences in the macroeconomic conditions. These are the

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15 We could alternatively use the ‘production approach’, which views financial institutions as producers of services for account holders. Output is measured by the transactions or documents processed over a given time period. Due to limitations in transaction level data on a bank-by-bank basis, we employ the ‘intermediation approach’.
GDP growth rate and the average growth of the inflation rate. Finally, technological changes over time are captured by a linear time trend \( t \).

4.4. Data

Data on the banks’ balance sheets and income statements are obtained from BankScope and cover the period 1999-2006. The sample used in the empirical analysis consists of quoted commercial banks from the EU-27. We incorporate all those banks for which at least four years are available over the sample period. This refinement allows us to distinguish reliably between random factors and bank inefficiency in the composite error term. The sources for the macroeconomic data are the European Statistical Service (Eurostat), the OECD database, and the World Economic Outlook Database of the International Monetary Fund. Where necessary, data are deflated using country GDP deflators.

5. Results

5.1. Cost efficiency estimates

Table 1 presents the mean cost efficiency scores for the first group of countries, that is, the traditional EU-15 member states. Efficiency increases when noninterest income is included in the output vector of the model by approximately 5%. However, no change is reported in the efficiency levels between the restricted and the unrestricted models when we consider OBS items instead of noninterest income.

To evaluate the importance of product diversification for bank cost efficiency, we proceed in testing the statistical significance of the observed differences in efficiency scores between the restricted and the unrestricted A model conducting the non-parametric Wilcoxon signed-rank test. It turns out that the p-value of the Wilcoxon t-statistic is below .05, which indicates that the mean score obtained from the restricted model is statistically lower than the one obtained from the unrestricted A model.

5.2. The effect of environmental variables on cost efficiency

The results for the cost frontier are rather meaningful. All the coefficients of input prices and output quantities are positive and statistically significant at the 1% level regardless of the model specification we examine (see Table 2).
Our findings report a positive relationship between inflation rate growth and total costs. This is to say, an increase in average inflation increases interest rates and hence the interest expense for banks. As expected, cost efficiency is reduced.

Moreover, a significant positive association between real GDP growth and total costs is documented. This implies that an increase in GDP leads to an increase in total costs, and thus to a fall in bank efficiency. This result is rather not in line with expectations. In particular, someone would anticipate that as countries become more prosperous, their banks acquire a better access to new technologies, which help them to produce more output using less input.

Regarding the bank-specific variable of the equity capital ratio, it turns out that it negatively affects total costs. In other words, banks’ financial capital has a positive impact on cost efficiency. That is, better-capitalized banks operate in higher efficiency levels. This can be explained by the fact that higher level of equity implies lower leverage and default risk, ceteris paribus.
References.


### Appendix: Tables

#### Table 1: Cost efficiency estimates, EU-15

<table>
<thead>
<tr>
<th>Model specification</th>
<th>Restricted</th>
<th>Unrestricted A (incl. noninterest income)</th>
<th>Unrestricted B (incl. OBS activities)</th>
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<td>Mean efficiency scores</td>
<td>0.49</td>
<td>0.54</td>
<td>0.49</td>
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#### Table 2: Regression results

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<th>Unrestricted A (incl. noninterest income)</th>
<th>Unrestricted B (incl. OBS activities)</th>
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<td>ln(other earning assets)</td>
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<td>equity capital</td>
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<td>-7.700***</td>
<td>-9.112***</td>
</tr>
<tr>
<td></td>
<td>(.377)</td>
<td>(.514)</td>
<td>(.382)</td>
</tr>
<tr>
<td>real GDP growth rate</td>
<td>.896***</td>
<td>.818***</td>
<td>.716***</td>
</tr>
<tr>
<td></td>
<td>(.060)</td>
<td>(.061)</td>
<td>(.067)</td>
</tr>
<tr>
<td>real average inflation rate</td>
<td>.189***</td>
<td>.193</td>
<td>.276***</td>
</tr>
<tr>
<td></td>
<td>(.086)</td>
<td>(.081)</td>
<td>(.0943)</td>
</tr>
</tbody>
</table>